Gate-dependent spin-orbit coupling in multielectron carbon nanotubes

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Gate-dependent orbital magnetic moment in carbon nanotubes
Supporting online material

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Estimating the band gap

The nanotube sample studied in the article is particularly regular in the many-electron regime (see data in article), while less so close to the band gap. The strong/weak coupling for shells in the valence/conduction band [1] indicates that the nanotube is a small band gap semiconducting nanotube [2]. Figure S1 shows the stability diagram in the region of the largest Coulomb peak spacings and the lowest currents. The very large diamond at $V_g \sim 0.8\,\mathrm{V}$ is interpreted as a result of the band-gap energy adding to the addition energy $\sim 50 - 60\,\mathrm{meV}$. To estimate the band-gap we subtract the average charging energy and level spacings for the first hole and first electron[3] *i.e.*, the average height of the neighboring diamonds ($\sim 25\,\mathrm{meV}$) yielding $E_g \sim 30\,\mathrm{meV}$. The band gap parameter appearing in the article[1] is defined as $\Delta_g = E_g/2 \sim 15\,\mathrm{meV}$, *i.e.* consistent with the value from the fit of $g_{\mathrm{orb}}(V_g)$ to Eq. 3 (Fig. 4 of the main manuscript).

Additional data

To supplement the excited state spectroscopy measurements of g_{orb} discussed in the article, the device was cooled again to 4.2 K and following the method of Ref. [4], g_{orb} values were extracted from the evolution of zero-bias Coulomb blockade peaks in a parallel magnetic field. Representative data is shown in Fig.

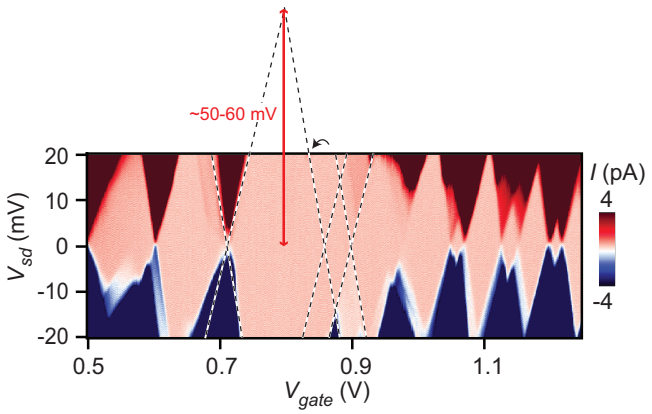

Figure S1: Stability diagram in the V_g-region of the band gap. A low current signal is observed at the position of the arrow leading to the diamond structure indicated by the lines.

S2 for two different V_g-regions; close to the gap (top) and for many electrons (bottom). The gate axis has been converted into energy by the α-factor which is measured from the corresponding stability diagrams as the ratio of Coulomb diamond heights (bias) to widths (gate). The orbital g-factor is extracted from the $B_{\|}$-dependence of the peak positions in Fig. S2 and displayed in Fig. 4 of the main manuscript (square data points). As discussed above, the regular 4-fold periodicity is absent in the vicinity of the gap impeding direct comparison to the 4-fold model. Instead g_{orb} was measured for all charge-states in the gate region indicated by the horizontal error bars in Fig. 4 of the main manuscript and the spread in resulting g_{orb}-values is indicated by the vertical error bars.

References

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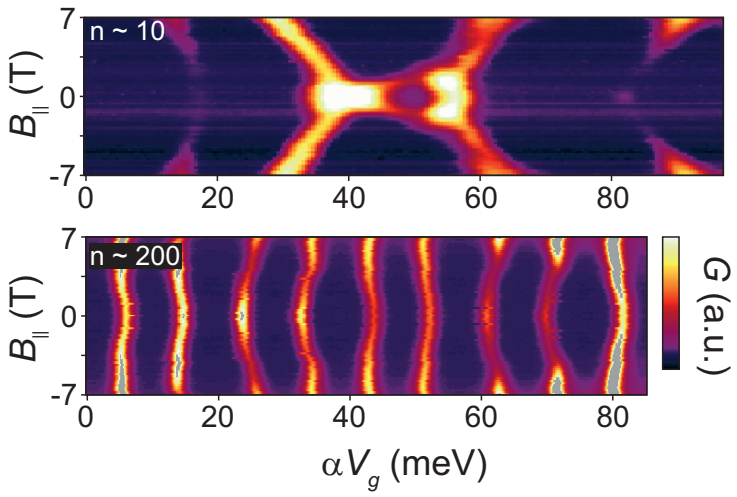

Figure S2: The evolution of Coulomb peaks in a parallel magnetic field for two different gate regions. Close to the gap (top) and in the many electron regime (bottom). The gate axis has been converted to energy by the α-factor which is extracted from the corresponding stability diagrams (see text). The $B_{\parallel}$-dependence of the peak positions yields g_{orb}.